OIPE JUN 3 0 2004 TRADEMARK OFFICE

Docket No.: SON -2070
(80001-2070)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:

Kenjiro WATANABE et al.

Application No.: 09/833,640 — Art Unit: 2655

Filed: April 13, 2001 — Examiner: Nabil Z. Hindi

For: OPTICAL ELEMENT, OPTICAL HEAD AND SIGNAL REPRODUCING METHOD — Conf. No. 3083

SUBMISSION OF CERTIFIED TRANSLATION OF PRIORITY DOCUMENT

MS Non-Fee Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

The Applicant, through its representatives and attorneys, hereby brings to the attention of the Examiner an English language translation of Japanese Application No. 2000-118554.

The above-identified application is entitled to benefit the filing date of Japanese Application No. 2000-118554. This Japanese Application has a priority date of April 14, 2000.

Please take this English language translation into account in the examination of this application and make its consideration of record. If the Examiner has any comments or suggestions that could place this application in even better form, the Examiner is requested to telephone the undersigned attorney at 202-955-3750.

Dated: June 30, 2004

Respectfully submitted,

By____________________

Ronald P. Kananen
Registration No.: 24,104
(202) 955-3750
Attorneys for Applicant

RADER, FISHMAN & GRAUER, P.L.L.C
1233 20th Street, N.W., Suite 501
Washington, D.C. 20036
Telephone: (202) 955-3750
Facsimile: (202) 955-3751
CUSTOMER 23353

IN THE UNTED STATES PATENT AND TRADE MARK OFFICE

APPLICANTS: Kenjiro WATANABE et al.

APPLICATION NO.: 09/833,640

FILING DATE: April 14, 2000

GROUP ART UNIT: 2655

EXAMINER: N. Z. Hindi

TITLE: Optical element, optical head and signal reproducing method

Hon. Commissioner of Patents and Trademarks,
Washington, D.C. 20231

SIR;

CERTIFIED TRANSLATION

I, Terue MIURA, am an official translator of the Japanese language into the English language and I hereby certify that the attached comprises an accurate translation into English of Japanese Application No. 2000-118554, filed on April 14, 2000.

I hereby declare that all statements made herein of my own knowledge are true and that all statement made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

June 23, 2004 — Terue Miura

Date — Terue MIURA

[Name of the Document] Application for Patent
[Reference Number] 0000262704
[Filing Date] April 14, 2000
[Destination] Commissioner, Patent Office of Japan
[International Patent Classification] G11B 07/13
[Inventor]
[Address or location] c/o Sony Corporation
7-35, Kitashinagawa 6-chome,
Shinagawa-ku, Tokyo, Japan
[Name] Kenjiro WATANABE
[Inventor]
[Address or location] c/o Sony Corporation
7-35, Kitashinagawa 6-chome,
Shinagawa-ku, Tokyo, Japan
[Name] Hitoshi TAMADA
[Applicant for Patent]
[Identification No.] 000002185
[Name] Sony Corporation
[Representative] Nobuyuki IDEI
[Agent]
[Identification No.] 100067736
[Patent Attorney]
[Name or Designation] Akira KOIKE
[Appointed Agent]
[Identification Code] 100086335
[Patent Attorney]
[Name] Eiichi TAMURA
[Appointed Agent]
[Identification Code] 100096677
[Patent Attorney]
[Name] Seiji IGA

[Indication of Charge]		
[Ledger Number of Prepayment]	019530	
[Amount of Payment]	21,000 yen	
[List of Submitted Articles]		
[Article Name]	Specification	1
[Article Name]	Drawing	1
[Article Name]	Abstract	1
[General Power of Attorney No.]		9707387
[Necessity of Proof]	Necessary	

[Document Name] Specification

[Title of the Invention]

Optical element, optical head and signal reproducing method

[Claims]

[Claim 1]

An optical element characterized by having embedded in a lens surface substantially perpendicular to an optical axis a conductive member whose diameter or width is smaller than the diameter of an optical spot on the lens surface.

[Claim 2]

The optical element as set forth in claim 1 characterized in that the conductive member is embedded on an optical axis of a lens symmetrically with respect to the optical axis, and an end point of the conductive member has a diameter smaller than the diameter of an optical spot on a lens surface and faces the lens surface.

[Claim 3]

The optical element as set forth in claim 1 characterized in that the conducive member is in a form of a line and embedded in the lens surface so as to cross an optical spot.

[Claim 4]

The optical element as set forth in claim 1 characterized by being a one selected from among a semi-spheric lens, a super solid immersion lens or an objective lens.

[Claim 5]

The optical element as set forth in claim 1 characterized in that the conductive member is made of any of a metal, a metalloid or a transparent conductive material having a different refractive index from the refractive index of the

lens material.

[Claim 6]

The optical element as set forth in claim 1 characterized in that the conductive member is provided with an electrode to provide a current.

[Claim 7]

An optical head having an optical element installed on a slider and reading a signal by illuminating an optical recording medium with a reading light, the optical head characterized in that the optical element has embedded in a lens surface substantially perpendicular to an optical axis a conductive member whose diameter or width is smaller than the diameter of an optical spot on the lens surface.

[Claim 8]

The optical head as set forth in claim 7 characterized in that the optical element is a one selected from among a semi-spheric lens, a super SIL or an objective lens.

[Claim 9]

The optical head as set forth in claim 7 characterized in that the optical element is integrated with a slider.

[Claim 10]

The optical head as set forth in claim 7 characterized in that a signal detecting optical element and a reference optical element are provided and a conductive member is embedded in a lens surface of the signal detecting optical element.

[Claim 11]

The optical head as set forth in claim 7 characterized in that the conductive member is provided with an electrode to provide a current.

[Claim 12]

A signal reproducing method characterized by comprising:

splitting a laser light from a same source for incidence upon an optical element to form two optical spots on a focal plane of the optical element;

disposing, in a position corresponding to one of the optical spots, a conductive member whose diameter or width is smaller than the diameter of the optical spot; and

reading a signal under the effect of an interference between return light beams, the optical spot on which the conductive member is disposed serving as a detection light and the other optical spot serving as a reference light, from an optical recording medium.

[Claim 13]

A signal reproducing method characterized by comprising:

illuminating an optical element with a laser light, disposing a conductive member in the position of an optical spot while providing a high frequency current to the conductive member; and

detecting an interaction between a conductive material on a surface of an optical recording medium and the conductive member by extracting a signal synchronous with the high frequency and reading a signal recorded in an optical recording medium.

[Claim 14]

The signal reproducing method as set forth in claim 13 characterized in that directions of the laser light deflecting surface and current are substantially perpendicular, or substantially parallel, to each other.

[Detail Description of the Invention]

[0001]

[Technical Field to which the Invention Pertain]

The present invention relates to a novel optical element capable of detecting a smaller mark than an optical spot, an optical head using the optical element and a signal reproducing method using the optical head.

[0002]

[Prior Art]

In the field of optical recording, it has been demanded to record a signal in a higher density. To meet such a demand, various recording and reproducing methods have been proposed.

[0003]

For example, in the technical field of the optical heads which read a signal by illuminating an optical recording medium with a reading light, it has been proposed to use a solid immersion lens (will be referred to as "SIL" hereunder) or a solid immersion mirror (will be referred to as "SIM" hereunder) as an optical element in order to write and/or read a signal in a high density, and a fringing light in a near field to read a signal with a rather higher numerical aperture (NA) than ever.

[0004]

[Problems to be Solved by the Invention]

On the other hand, it has been proposed to dispose a metal needle at the end of an interference microscope in order to measure the shape of an object under examination.

[0005]

The metal needle is sharpened to have a point of about 100 nm. This sharp end will have an electromagnetic interaction with a very thin coating of Cr on the surface of the object

under examination. The magnitude of the interaction depends upon the distance between the needle point and Cr coating.

[0006]

A light converged to the needle point will have the wave phase thereof shifted due to the above electromagnetic interaction. The wave phase shift is on the order of $10^{-4}/\sqrt{Hz}$ but can be detected using the phase difference interference between the needle point and a light from a remote location (refer to "Apertureless Near-field Optical Microscope" F. Zenhausern, M. P. O' Boyle and H. K. Wickeramasinghe, Appl. Phys. Lett. 65(13), Sep. 2, 1994, and "Optical Data Storage Read Out at 256 Gbits/sq. in." Y. Martin, S. Rshton and H. K. Wickeramasinghe, Appl. Phys. Lett. 71(1), Jul.7, 1997). It is expectable that the above principle permits detection with a higher resolution than by the SIL and SIM. However, the principle has not yet been used in practice in the field of optical recording. For example, the cantilever has to always be at a constant distance from the surface of an optical disc to effectively implement the principle in the technique disclosed in the above documents, the optical disc is illuminated with a laser light other than the reading light from behind the cantilever and an electric servo control is performed according to the movement to control the distance between the needle point and disc to be tens of nm. However, since the cantilever is moved slowly, no high-speed reading is possible.

[0007]

In view of the situation of the prior art, an object of the present invention is to facilitate the introduction of the above principle into the field of optical recording.

[0008]

More particularly, the present invention has an object of providing an optical element which can detect a smaller mark than an optical spot focused by the optical system, optical head using the optical element and a signal reproducing method using the optical head.

[0009]

[Means for Solving the Problems]

The above object can be attained by providing an optical element having embedded in a lens surface substantially perpendicular to an optical axis a conductive member whose diameter or width is smaller than the diameter of an optical spot on the lens surface.

[0010]

Also an optical head of the present invention is characterized by having an optical element installed on a slider and reading a signal by illuminating an optical recording medium with a reading light, wherein the optical element has embedded in a lens surface substantially perpendicular to an optical axis a conductive member whose diameter or width is smaller than the diameter of an optical spot on the lens surface.

[0011]

Further, a signal reproducing method of the present invention is characterized by splitting a laser light from a same source for incidence upon an optical element to form two optical spots on a focal plane of the optical element, disposing, in a position corresponding to one of the optical spots, a conductive member whose diameter or width is smaller than the diameter of the optical spot and reading a signal under the effect of an interference between return light beams,

the optical spot on which the conductive member is disposed serving as a detection light and the other optical spot serving as a reference light, from an optical recording medium.

[0012]

The basic principle of the present invention is such that a subtle phase change of the light is detected which is caused by the electromagnetic interaction between the conductive member embedded in the optical element and a conductive material on the surface of the optical recording medium.

[0013]

The conductive member has a diameter or width smaller than the diameter of the optical spot on the lens surface. Therefore, a smaller mark than the optical spot can be detected.

[0014]

Also, the conductive member is embedded integrally with the optical element. Thus, the optical head needs no complicated servo control mechanism and a high-speed reading is possible.

[0015]

[Preferred Embodiments of the Invention]

Below, an optical element, optical head and signal reproducing method being applied the present invention will be described in detail with reference to the drawings.

[0016]

Referring now to FIGS. 1 to 4, there are illustrated embodiments of the optical element each having a conductive member embedded in a semi-spheric lens thereof. The semi-spheric lens is an example capable of phase detection in a near field where an SIL is used.

[0017]

In the optical element shown in FIG. 1 for example, a conical metal piece M is embedded as the conductive member in the center of the optical axis of the semi-spheric lens L. FIG. 2 shows an optical element having embedded in the semi-spheric lens L thereof as the conductive member a metal piece M whose diameter becomes stepwise decreased towards the end of the semi-spheric lens L.

[0018]

FIG. 3 shows an embodiment of the optical element having embedded in the semi-spheric lens L a fine metalloid piece S (for example, Si) of hundreds of nm in diameter. FIG. 4 shows an embodiment of the optical element having a conical transparent conductive material T embedded as the conductive member in the center of the optical axis of the semi- spheric lens L thereof.

[0019]

In any of the above optical elements, there is embedded the conductive member (metal piece M, metalloid piece S and transparent conductive material T) whose end diameter is smaller than that of an optical spot focused in a focal plane F by the semi-spheric lens L, and end point is directed into the optical spot in the focal plane F of the semi-spheric lens L.

[0020]

Note that in the SIL such as in each of the above optical elements, a light will be incident upon the semi-spheric lens L perpendicularly. At this time, the diameter of the optical spot on the bottom of the semi-sphere (focal plane F) depends upon wavelength/NA. Numerical aperture (NA) is nSin θ (n: refractive index).

[0021]

In the above construction, the conductive member (metal piece M, metalloid piece S or transparent conductive material T) should be formed to have such a shape as will not interfere with a light incident upon the semi-spheric lens L, namely, as will not refract the light or will not influence the locus of the light by reflection.

[0022]

Thus, since the central portion of the optical axis is cut off by the metal or metalloid piece before the light is incident upon the lens, the optical spot on the lens bottom (focal plane F) will be an optical spot of an ultra- high resolution.

[0023]

The transparent conductive material T will also not disturb the light locus when it is formed conical.

[0024]

Since a geometric error of an approximate half of a wavelength used will not disturb the light and thus allowed, a metal ball of hundreds of nm in diameter, for example, can be embedded.

[0025]

Also, the present invention is applicable to a super SIL as shown in FIG. 5 and an SIM as shown in FIG. 6, in addition to the aforementioned SIL, also to an objective lens.

[0026]

When the above optical element is used to read pits and grooves in an optical disc for example, an electromagnetic interaction will take place between the conductive member embedded in the optical element and a recording layer (for example, Cr) coated on the surface of the optical disc. The electromagnetic interaction depends upon the distance between

the conductive member and Cr-coated surface of the optical disc.

[0027]

When a light is focused at a needle point (end portion of the conductive member), the focused light will incur a light-wave phase shift due to the above electromagnetic interaction. By detecting this phase shift by the use of the effect of a phase difference interference with the reference light, a reading is possible, taking the diameter of the end point of the conductive member as a resolution, and read smaller pits and grooves than the focus optical spot. More particularly, a signal is read by splitting a laser light from the same source for incidence upon an optical element to form two optical spots on the focal plane of the optical element, disposing, in a position corresponding to one of the optical spots, a conductive member whose diameter or width is smaller than the diameter of the optical spot, and taking the optical spot incident on the conductive member as a detection light while taking another optical spot as a reference light and reading the signal under the effect of an interference between return light beams from the optical recording medium.

[0028]

The measured phase difference is expressed by formula 1. The magnetization factor χ of Si is 14.0+14 i and the phase difference $\Delta\phi$ depends upon the product with χ(=-1.4+37.4 i) of Cr coated on the optical disc surface.

[0029]

Formula 1

phase difference

$$\Delta\phi = \frac{5}{9}(ka)^3 \frac{NA^2}{n^2} Re(\chi_1, \chi_2)$$

a: end point diameter of probe

NA: Numerical aperture of lens

$\chi 1$, $\chi 2$: Magnetization factor

[0030]

Therefore, a conductive material in which the imaginary part of the magnetization factor χ is large such as Au (χ=0.188+5.39 i) or Al (χ=-2.80+8.45 i) is desirably used as the conductive member (metal piece M, metalloid piece S or transparent conductive material T) besides Cr and Si.

[0031]

As another example of such conductive materials, there may be disposed a wire W of hundreds of nm in width to cross the optical spot P on the focal plane F of the SIL as shown in FIG. 7. In this case, electrodes D1 and D2 may be provided at opposite ends of the wire W for a current to flow through the wire W, whereby the electromagnetic interaction can be increased.

[0032]

For example, a laser light can be emitted to the SIL, a high frequency current is supplied to the wire W, a signal synchronous with the high frequency is extracted to detect the interaction between the conductive material on the optical disc surface and the wire W, and thus a signal recorded in the optical recording medium can be read with a high sensitivity.

[0033]

Making a direction of the laser light deflecting surface and a direction of the current substantially perpendicular or substantially parallel may allow to detect, with a high accuracy, a change of the deflecting surface of the recording layer in the optical recording medium.

[0034]

Also, by reading while moving the optical element in a direction perpendicular to the wire W, it is possible to read a signal with a resolution which is the width of the wire W.

[0035]

Next, the optical head using the aforementioned optical element will be described, also the signal reproducing method using the optical head will be described.

[0036]

Referring now to FIG. 8, there is illustrated an embodiment of the optical head according to the present invention, in which the slider and optical element are integral with each other and a conductive member is embedded in the optical element.

[0037]

The optical head includes a glass slider 1 which serves as a lens, and a metal piece 2 embedded in the slider 1. In this optical head, a laser light emitted from a laser diode LD is guided to the glass slider 1 via a beam splitter BS and condenser lens L1, and converged to the surface of an optical recording medium 3, to thereby read a signal from the optical recording medium 3.

[0038]

In this embodiment, the laser light from the laser diode LD is split at a slight angle by a Wollaston prism 4 disposed between the beam splitter BS and condenser lens L1. One of the split light beams is converged to the end point of the metal piece 2 as a detection light HK while the other is converged, as a reference light HS, to a position where the metal piece 2 is off the focus spot.

[0039]

It should be noted that in FIG. 8, the condenser lens L1 and glass slider 1 are shown as if they were separate from each other but they should be integral with each other.

[0040]

A return light is guided by the beam splitter BS to a photodetector PD for detecting. The return light is also split by the Wollaston prism 5.

[0041]

When reading a signal from the optical recording medium 3 by means of the optical head this constructed, a phase difference between the detection ling HK and reference light HS is detected by interferometry.

[0042]

The difference between the end point of the metal piece 2 and a recording layer (conductive layer) on the surface of the optical recording medium will vary from when the end point of the metal piece 2 is opposite to a convex portion of a pit on the optical recording medium to when the end point of the metal piece 2 is opposite to a concave portion of the pit. Thus, the magnitude of the electromagnetic interaction will vary, so the phase shift will change slightly.

[0043]

The change in phase shift is detected by the interferometry to read the pit (signal).

[0044]

FIGS. 9 and 10 show an embodiment of the optical head having an SIM installed therein. As shown, in this optical head, an SIM 22 is mounted on a glass slider 21 and secured to the latter with an adhesive layer.

[0045]

The glass slider 21 is supported on a suspension 23 and installed in an optical disc drive or the like.

[0046]

The glass slider 21 is 291 μm thick and can be levitated 60 nm.

[0047]

The glass slider 21 has a side 21 a thereof facing the optical recording medium. The side 21a is formed from a rail surface 24, a front step 25, and a vacuum channel 26. The rail surface 24 is convex, and the front step 25 is recessed 0.35 μm from the rail surface 24. The vacuum channel 26 is recessed about 3 μm from the rail surface 24.

[0048]

Therefore, at the time of levitation, the rail surface 24 will be nearest to the surface of an optical disc.

[0049]

The vacuum channel 26 has a center island 27, as high as the rail surface 24, which the bottom (focal plane) of the SIM 22 will face. A Si wire 28 of 300 nm is provided on the center island 27 as a conductive member.

[0050]

The Si wire 28, detection light spot 29 and reference light spot 30 are located in a relationship as shown. That is, the Si wire 28 is disposed to cross the detection light spot 29, and the reference light spot 30 is positioned off the Si wire 28.

[0051]

Also the Si wire 28 has lead wires 31 and 32 connected to both ends thereof, respectively, so that a current can be supplied to the Si wire 28. The lead wires 31 and 32 are disposed on the bottom of the vacuum channel so as not to influence

the levitation, and a 300 nm-wide recess for laying the Si wire 28 is formed in the center of the center island 27 being also the rail surface.

[0052]

The Si wire 28 may be formed by forming the glass slider 21 for example, then forming a recess of 300 nm in width and 500 nm in depth by patterning, sputtering Si, removing the Si material from other than the recess by the lift-off method, and then by kiss-lapping, for example.

[0053]

The SIL may be constructed similarly. FIG. 11 shows an example SIL in which a semi-spheric lens 41 is embedded in a glass substrate 42 and integrated with a condenser lens substrate 43.

[0054]

In this optical head, the optical system is so constructed to project to the lens a parallel light split at a slight angle by the Wollaston prism, and a spot focused by the lens defines a light spot on the slider bottom.

[0055]

At the slider bottom, the spot size was 0.6 µm (for NA=1.8) in the example SIM slider. It was 0.7 µm(for NA=1.0) in the case of SIL slider.

[0056]

The two spots were arranged about 2 µm off each other. The optical disc has pits and lands of 50 nm in length formed in a glass substrate thereof and also has a Cr coating of 50 nm in thickness formed on the surface.

[0057]

The slider was levitated 40 nm (at a linear velocity of 10 m/s) on the optical disc.

[0058]

While a weak current having a high frequency of 100 MHz to 4 GHz (f_0) (sufficiently higher than the data rate) is supplied to the lead wires, a signal is acquired by synchronizing a differentiation between the two split light beams with the high frequency (f_0), thereby permitting to detect a random pattern corresponding to the length of a mark of 50 nm on the optical disc.

[0059]

Similarly, recording mark can be detected on an optical disc in which information is recorded by means of pits and lands formed on the aforementioned substrate as well as on a phase-change type optical disc. In a phase-change type optical disc, recording marks different in refractive index are photo-thermally formed to a signal recording layer formed from a phase- change material such as GeSbTe. A difference in refractive index in the phase- change type optical disc means a difference in magnetization factor X. Therefore, according to the present invention, recording marks of small pit length formed in the phase-change optical disc could be detected in the same manner as in the above.

[0060]

Similarly, by forming the conductive member from a highly permeable material such as Permalloy or a ferromagnetic material such as iron, it was possible to detect fine magnetic domains on a magneto-optic or magnetic recording medium.

[0061]

For example, a Permalloy piece of 200 nm in width may be disposed on the slider bottom, and a high frequency current be supplied to the Permalloy piece. A local fine magnetic field thus developed will incur a slight change in magnetic field

distribution due to the upward and downward magnetic domains on the optical disc. The change in magnetic field distribution is detected as a change in light phase due to an interaction with the light.

[0062]

As having been described in the foregoing, a small spot defined by a near-field optical system is used and a smaller conductive member than the light spot is focused on the optical disc, thereby permitting to detect pits and lands of some 10 nm on an optical disc and fine magnetic domains on a magnetic recording medium.

[0063]

[Effect of the Invention]

As will be seen from the foregoing description, according to the present invention, a finer mark than an optical spot can be detected.

[0064]

Also, the present invention may not require a complicated servo control mechanism, and may implement a high-speed reading.

[Brief Description Of Drawings]

[Fig. 1]

FIG. 1 is a schematic view of an example SIL in which a metal is embedded.

[Fig. 2]

FIG. 2 is a schematic view of another example SIL in which a metal is embedded.

[Fig. 3]

FIG. 3 is a schematic view of an example SIL in which a fine Si is embedded.

[Fig. 4]

FIG. 4 is a schematic view of an example SIL in which a transparent conductive material is embedded.

[Fig. 5]

FIG. 5 is a schematic view of an example super SIL.

[Fig. 6]

FIG. 6 is a schematic view of an example SIM.

[Fig. 7]

FIG. 7 is a schematic view of an example SIL in which a conductive member is embedded.

[Fig. 8]

FIG. 8 schematically illustrates an example construction of the optical head according to the present invention.

[Fig. 9]

FIG. 9 is a schematic side elevation of an example optical head having an SIM installed thereon.

[Fig. 10]

FIG. 10 is a generally plan view showing the side of the optical head shown in FIG. 9, facing the optical recording medium.

[Fig. 11]

It is a plan view showing a conventional heat press apparatus or a card manufacturing apparatus.

[Description of Codes]

1 glass slider, 2 metal piece, 22 SIM, 29 Si wire

[Document Name] Drawings

Figure 1

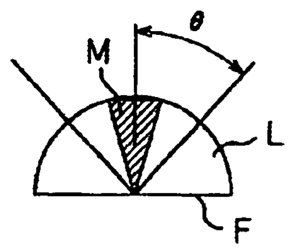


Figure 2

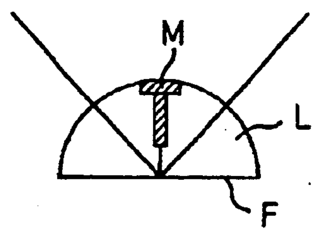


Figure 3

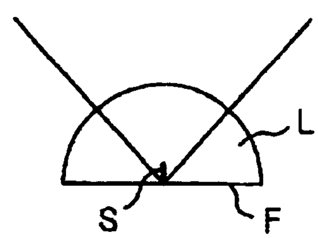


Figure 4

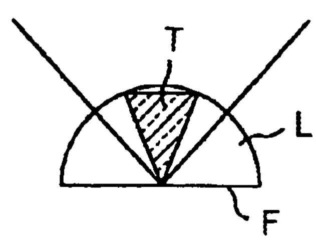
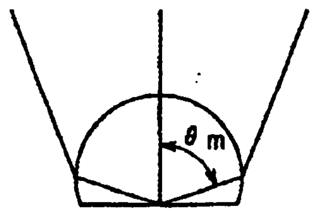
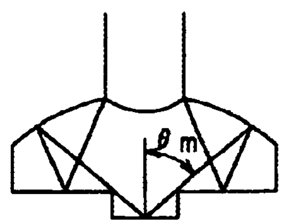


Figure 5



$NA = n \times n \, \mathrm{Sin}\, \theta$

Figure 6



$NA = n \, \mathrm{Sin}\, \theta$

Figure 7

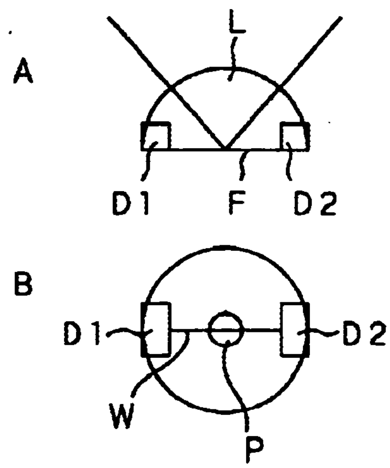


Figure 8

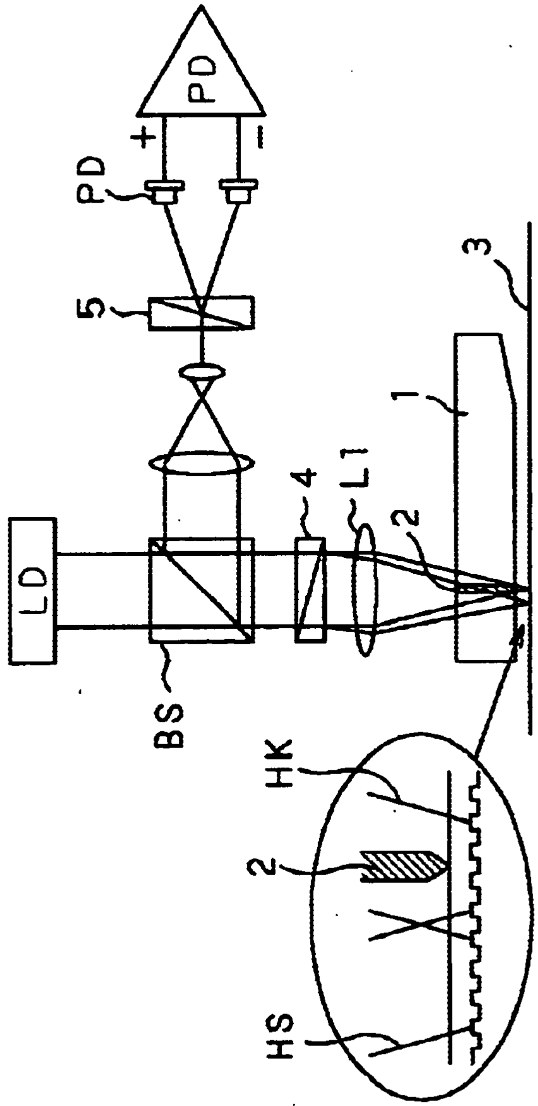


Figure 9

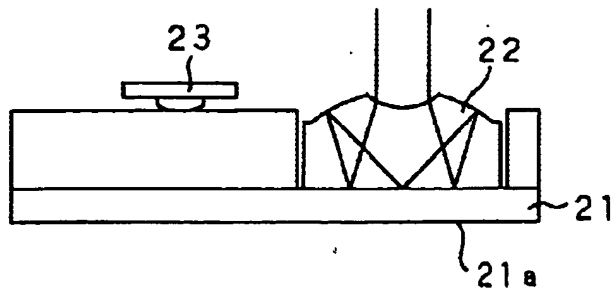


Figure 10

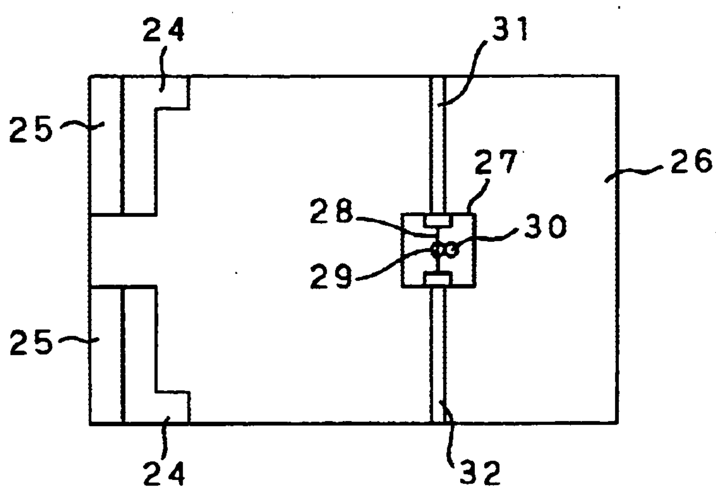
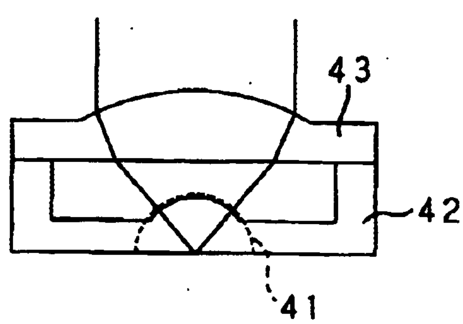


Figure 11



[Name of Document] Abstract

[Abstract]

[Problem] High-speed reading of a smaller mark than an optical spot is possible.

[Solving means] An optical element is provided in which in a lens surface substantially perpendicular to the optical axis of the lens, there is embedded a conductive member whose diameter or width is smaller than the diameter of an optical spot incident upon the lens surface. The optical element is used in an optical head, which reads a signal by illuminating an optical recording medium with a reading light. The basic principle of this optical head is such that a subtle phase change of the light is detected which is caused by the electromagnetic interaction between the conductive member embedded in the optical element and a conductive material on the surface of the optical recording medium. For example, the interference between return light beams from the optical recording medium is used to read a signal. Alternately, a high frequency current is supplied to the conductive material and a signal synchronous with the high frequency is extracted to detect the interaction between the conductive material on the optical recording medium and the conductive member, to thereby read a signal recorded in the optical recording medium.

[Selected Figure] Fig. 1